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EXTENSION FOR INCREASED DATA COLLECTION OF

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Some sections of this report have been completed in collaboration with Mr. J.D. Farina.

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Lasers, Coherence Theory, Electromagnetic Propagation, Highly Directional Beams, Variable Coherence Sources.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes our experimental findings. It is divided into 3 sections: the first provides a general introduction to the main problem of quasi-homogeneous sources. The second section contains the important experimental findings from far field measurements. The third summarizes our efforts to perform near field coherence measurements.

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INTRODUCTION

In the final report entitled "Development of Quasi-homogeneous Optical Sources" (Grant DAAG29 78 G 0098) we have summarized the theoretical background related to the field of partially coherent sources and discussed the procedure adopted in our laboratory to construct a quasi-homogeneous source.

It is worth emphasizing that the quasi-homogeneity requirements[1] refer to statistical properties of the radiated field. Such properties are not necessarily verified just because reasonable precautions are exercised in the manufacturing of the source. For example, it is intuitively obvious that if the partially coherent source in question is to be produced by illumination of a phase screen with the laser, one should take special care to insure a homogeneous distribution of surface inhomogeneities on the phase screen. Also one would intuitively expect that if the field coherence length is to be much larger than the wavelength of light, a similar constraint should hold for the typical <u>transverse</u> dimensions of the surface roughness of the phase screen. On the contrary, our intuition does not provide much help in interpreting the role played by the rms <u>thickness</u> of the surface roughness in setting the properties of the scattered light.

The above comments serve to emphasize that while the construction of our phase screens was carried out with certain reasonable requirements in mind, the quasi-homogeneous nature of the source had to be tested as critically as if the laser-plus-phase screen combination was actually just a black box containing an unknown radiator.

The most apparent feature of a quasi-homogeneous source is the highly unidirectional aspect of the emitted radiation. Qualitative and quantitative evidence of this effect has already been provided in our previous final report. Two additional theoretical predictions which are expected to hold under quasi-homogeneity conditions concern the independence of the far zone angular intensity distribution on the shape and size of the illumination profile at the source and the dependence of the far field degree of coherence on the source intensity distribution. The latter property is a consequence of a reciprocity theorem which was first established by Carter and Wolf[2].

The verification of these properties of a quasi-homogeneous source has been the main goal of our experimental efforts during the period July 1, 1979 thru September 30, 1979. In addition, we have nearly completed the assembly of a microcomputer control and data collection unit which is presently operating in our laboratory.

A detailed description of these activities is provided in the three sections of this report.

FAR FIELD MEASUREMENTS

The independence of the far field intensity distribution on the size and shape of the illumination area at the source plane is one of the most striking properties of quasi-homogeneous sources which have been demonstrated experimentally. The experimental set up which we used to demonstrate this effect is shown in figure 1. As described in our final report for contract #DAAG29-78G-0098, we illuminated a rotating phase screen at normal incidence with various intensity distributions while monitoring the far field intensity as a function of scattering angle. In our previous work we used Gaussian intensity distributions of various widths to verify that the sources which we produced were indeed quasi-homogeneous sources.

Our most recent effort was to investigate the behavior of quasi-homogeneous sources illuminated with intensity distributions other than Gaussian. To study this effect we used several different intensity distributions including Gaussians, truncated Gaussians, rectangular and the TEM_{01}* transverse mode of our HeNe laser. In each case, the intensity distribution in the far field remained unchanged to the accuracy with which we were able to measure. Some of the source illumination functions along with the corresponding far field intensity distributions are shown in Figures 2-5. For each of the cases shown in these figures, the effect of changing the illumination function is unmeasurable. It is worth noting that even when the conditions for quasi-homogeneity are not satisfied, as in Figure 4, where the intensity across the source plane varies quite rapidly, the far field invariance is still achieved. This suggests that the condition which states that the intensity must be slowly varying everywhere in the source plane is too stringent and could be restated to say that the intensity at the source should be slowly varying over the majority of the source plane.

The computer system which was outlined in our proposal is designed to automate data collection and enable high resolution large angular scans. The implementation of the computer system was delayed because of long delivery times (i.e. the delivery time for the memory was about two months). At present, the computer is operating in our laboratory but since software still must be refined, the system will not be operating as the primary measuring device until mid-February. This system seems to be very promising for studies of quasi-homogeneous sources not only in the far field, but also in the analysis of coherence data in the near field, and statistical studies of the rotating disk system which will provide insight into the ensemble averaging performed by the rotation of the disk. A schematic drawing of this system is shown in Figure 6 along with a block diagram of the stepper motor controllers which are now in use and will be interfaced with the computer in the future.

COHERENCE MEASUREMENTS

As stated in our proposal, one of the important properties which governs the behavior of quasi-homogeneous sources is the mutual coherence function at the source. We had proposed to measure this function using an improved version of the reversing front interferometer which is a modified Michelson interferometer. The improvements which we made consisted of using high quality optical components for the retroreflector and beam splitter. Our attempt to redesign our own revers..g front interferometer failed to overcome the limitations of our original design which seem to be inherent in an instrument of this type. The resolution which we were able to attain was approximately 100 μm which is at least an order of magnitude larger than would be acceptable for this measurement. Since we believe that the shortcomings of the reversing front interferometer would be present in any reasonable design, we have abandoned its use for the coherence measurements. To carry out these measurements we have designed a new type of instrument which does not possess the same inherent limitations as the reversing front interferometer.

The new instrument is a modified Mach-Zehnder interferometer. The modification consists of an imaging system used in conjunction with the standard Mach-Zehnder interferometer to allow mixing between images to obtain an interference pattern. The resulting interference pattern can easily be analyzed to obtain the mutual coherence function. Although it is still in the construction stages, we feel that this device is very promising based on our experience with the reversing front interferometer. We will report on this in the near future.

FIGURE CAPTIONS

1) A schematic drawing of the experimental set up used to measure the far field intensity distributions.

2) A typical far field intensity distribution obtained with a Gaussian intensity distribution in the source plane. The variance of the mutual coherence function σ_g, of the source is 8.8 μm and these measurements were obtained at a distance of 12.5 meters from the source.

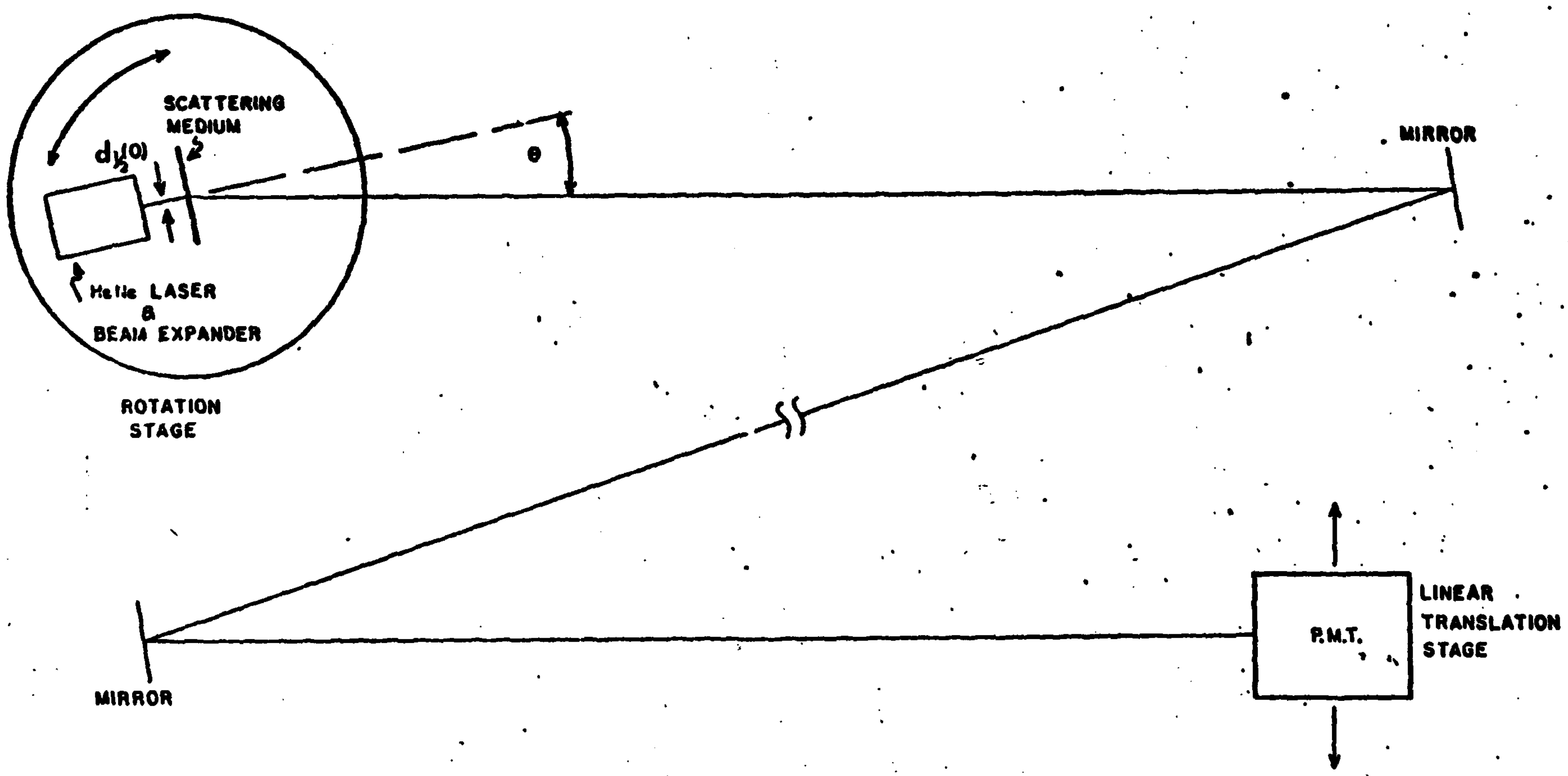
3) The far field intensity distribution obtained by illuminating the same source as in Figure 2 with a truncated Gaussian (upper right). The horizontal scale is the same as in Figure 2.

4) The far field intensity distribution obtained by illuminating the same source as in Figure 2 with a rectangular intensity distribution (upper right). The horizontal scale is the same as in Figure 2.

5) The far field intensity distribution obtained by illuminating the same source in Figure 2 with the TEM_{01}* mode of our laser. The horizontal scale is the same as in Figure 2.

6) a. A block diagram of the computer system used to control scanning in the far field measurements.

b. A block diagram of the stepper motor controllers which can be interfaced with the computer. Both rotation and translation stages are driven by similar controllers.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$d_{1/2}(0)$
θ
MIRROR
HeNe LASER & BEAM EXPANDER
ROTATION STAGE
MIRROR
P.M.T.
LINEAR TRANSLATION STAGE

FIGURE #1

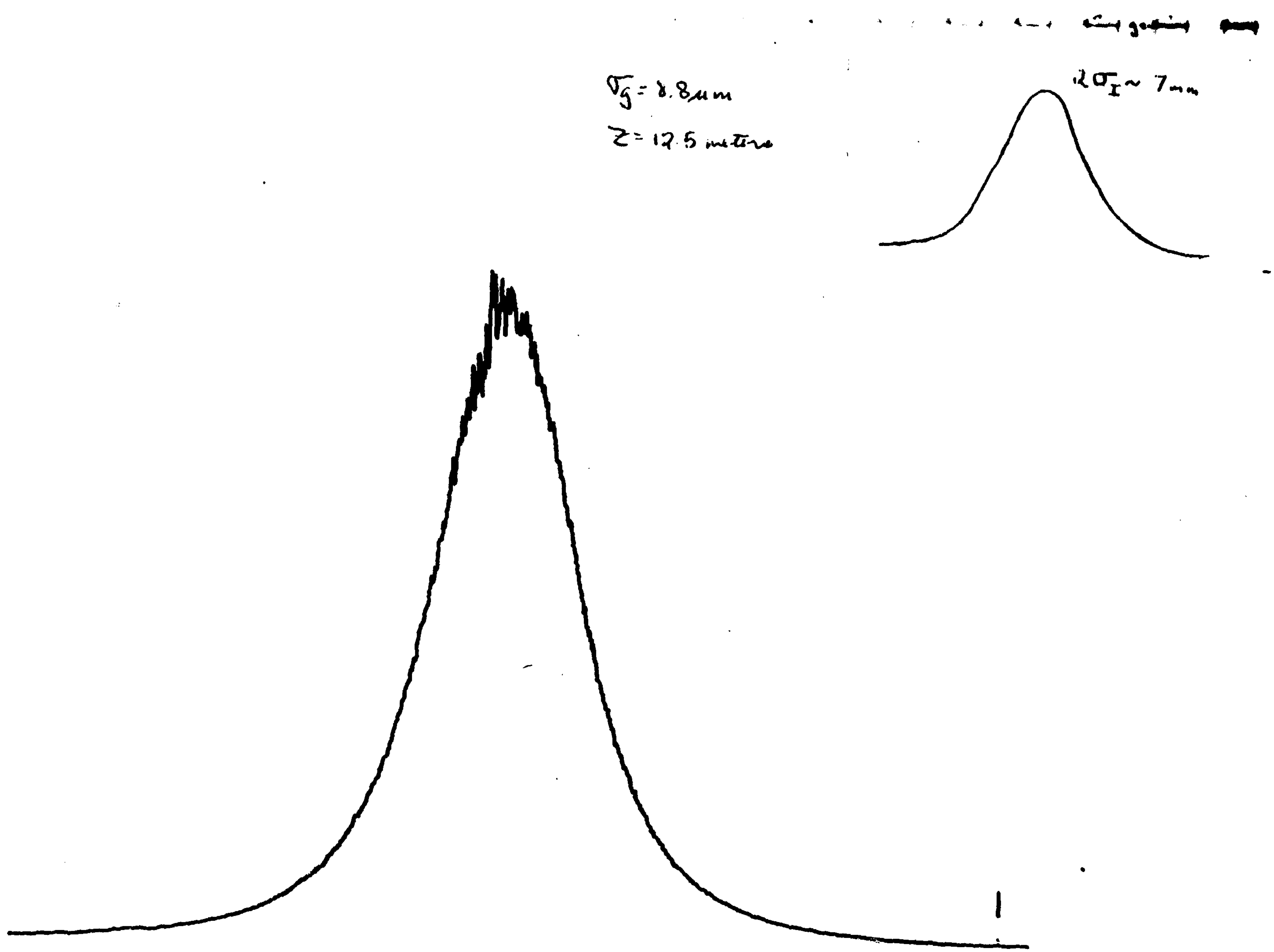


FIGURE #2

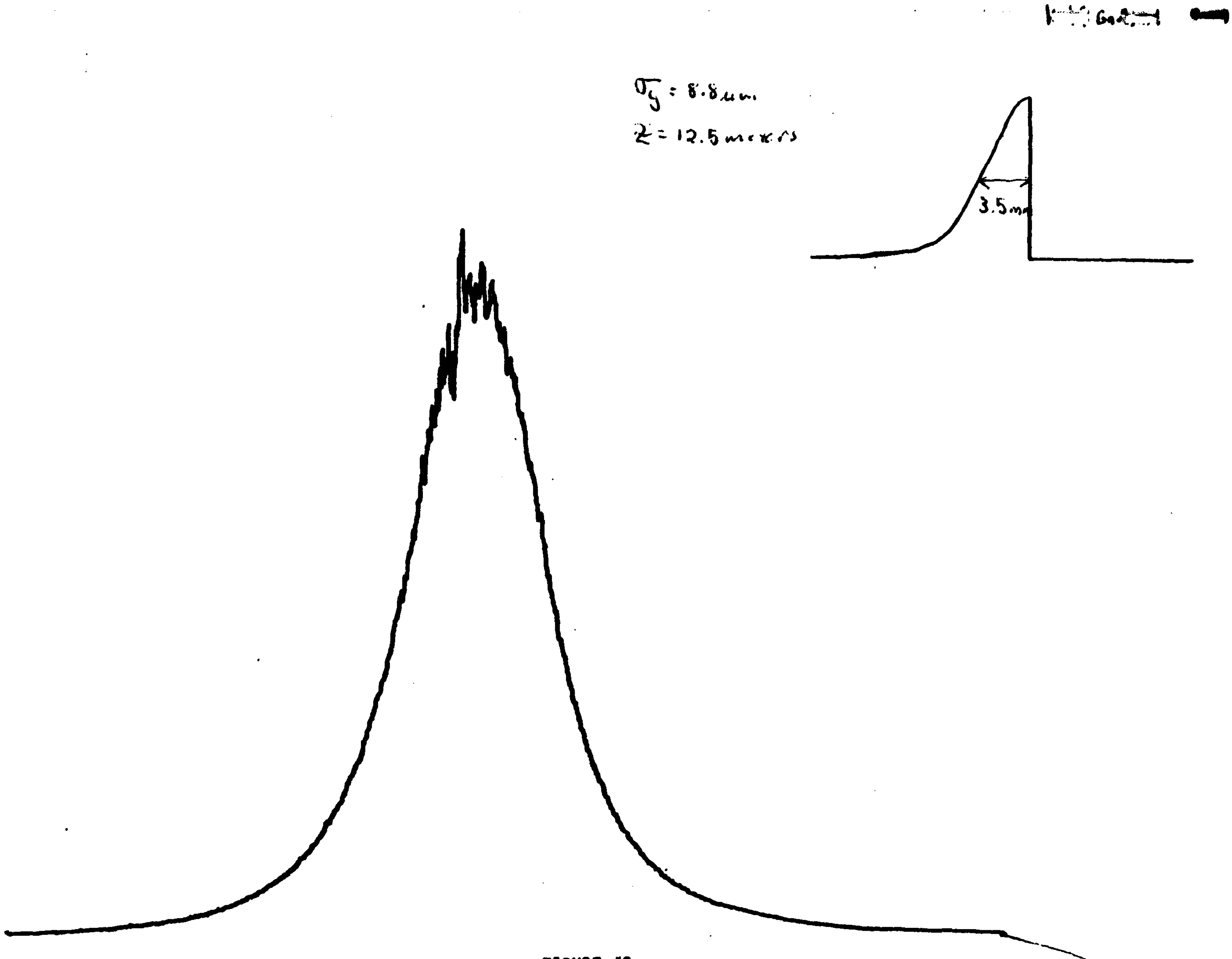


FIGURE #3

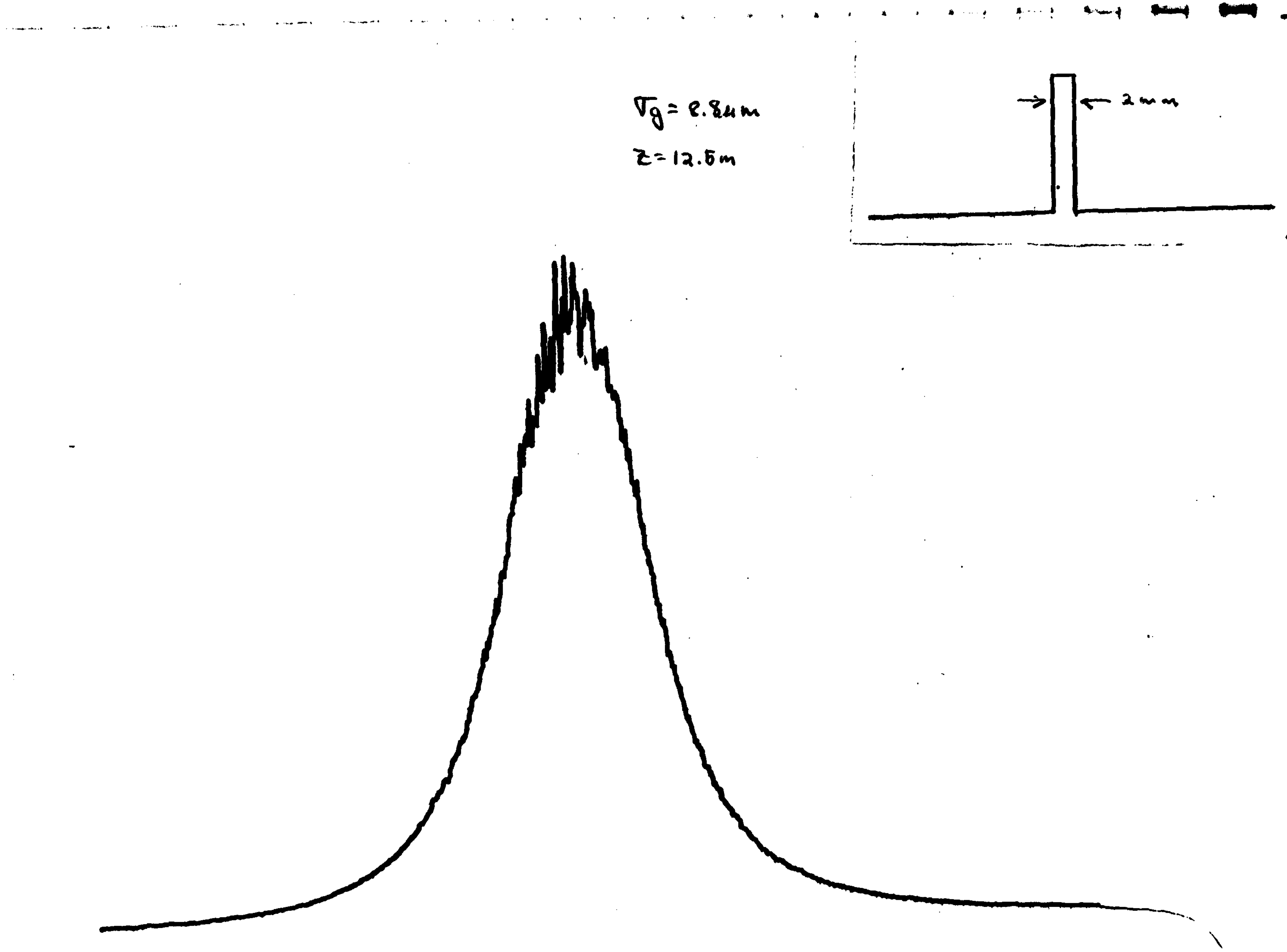


FIGURE #4

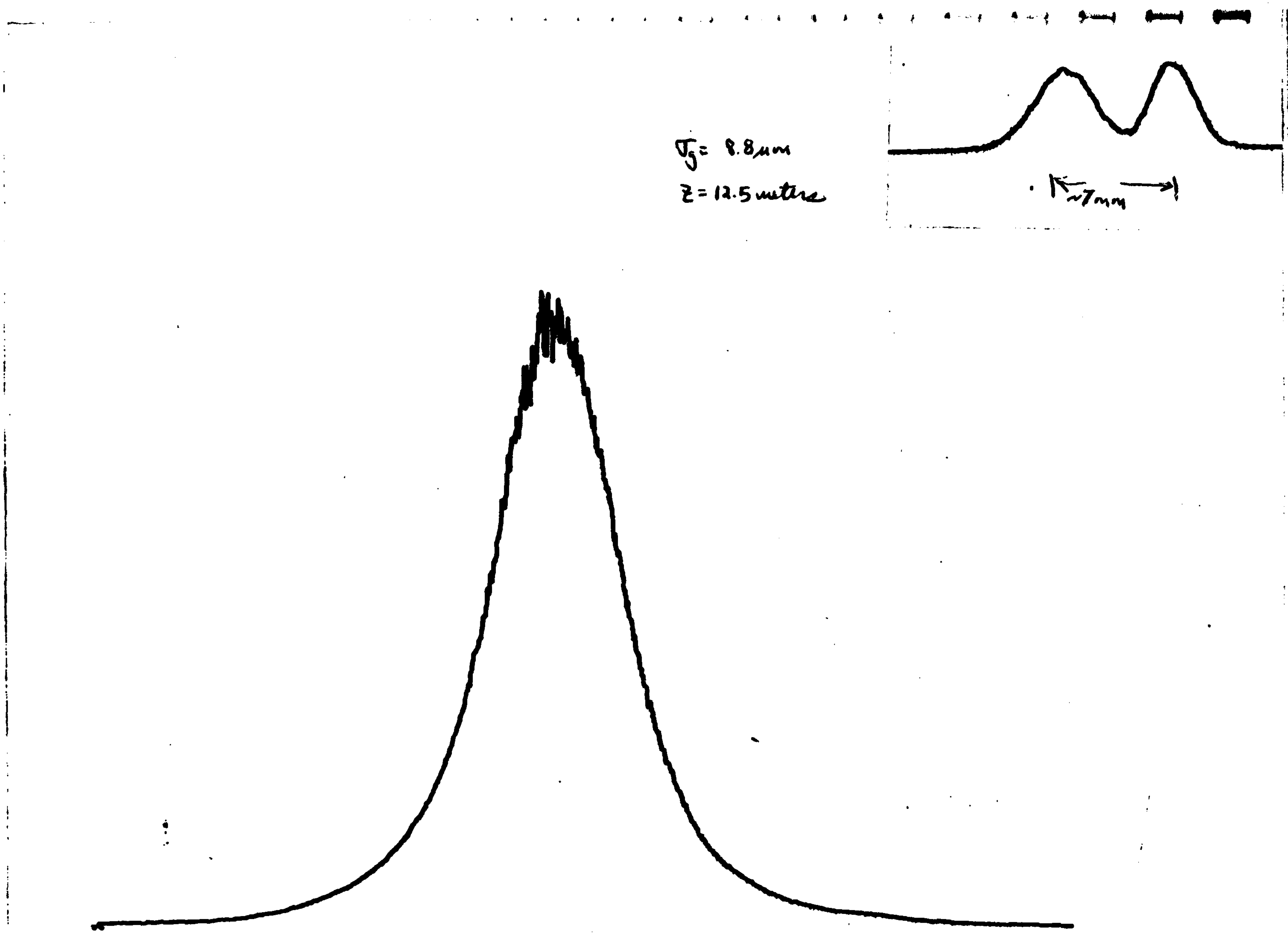


FIGURE #5

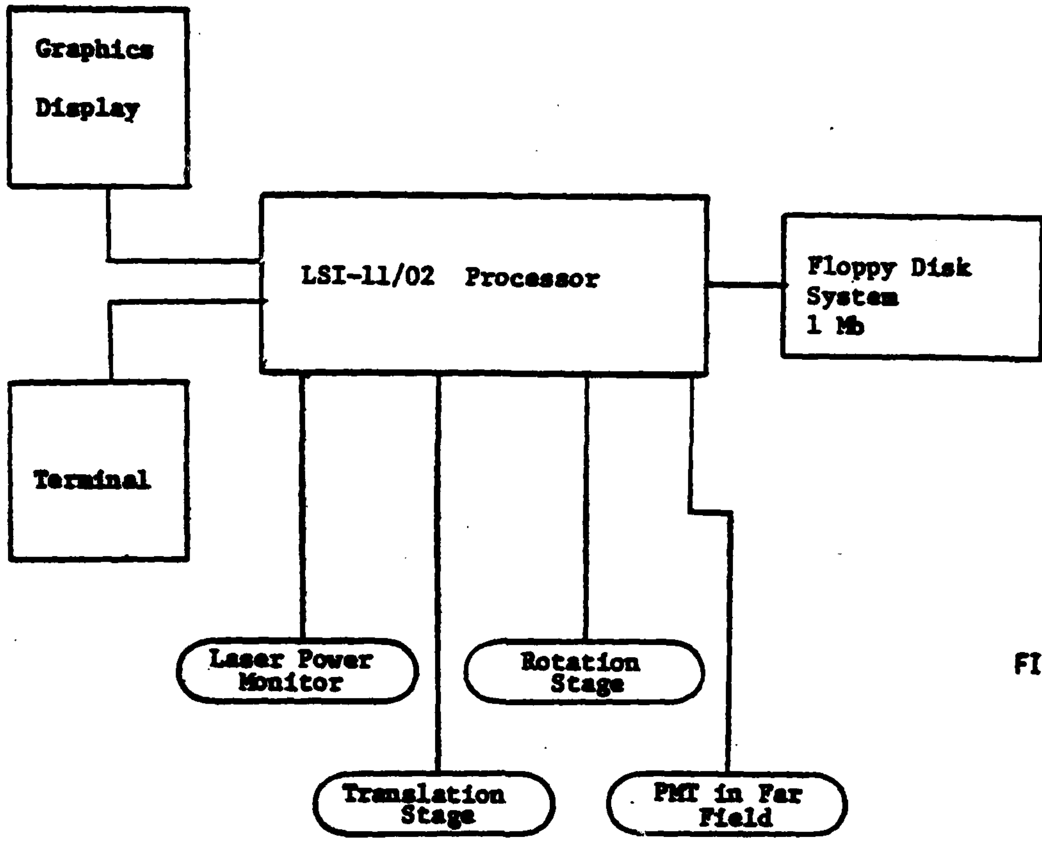
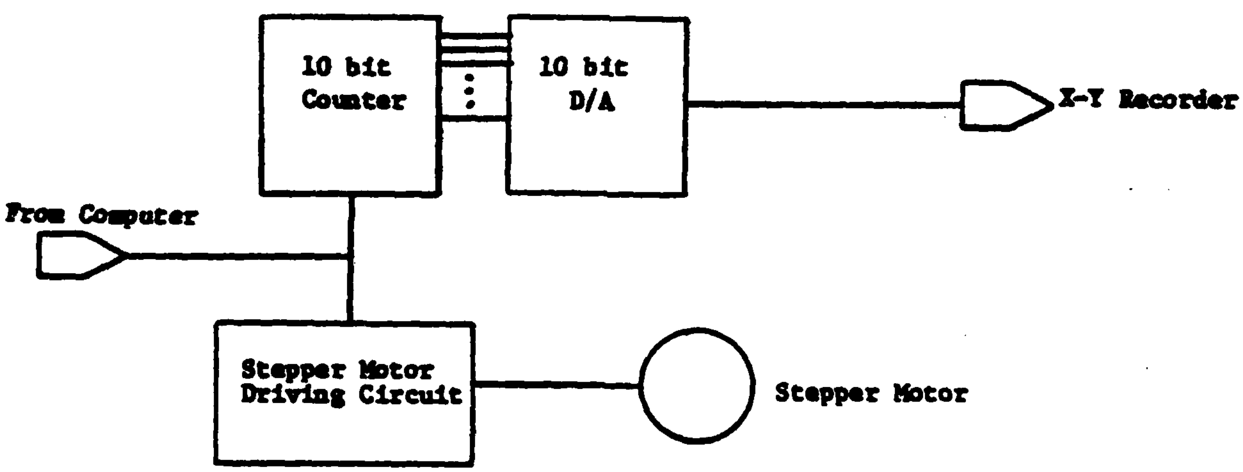


FIG. 6A

FIG. 6B



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